ENERGY PROGRAM REPORT

UCID-19227-87

U.S. ENERGY FLOW - 1987

I. Y. Borg
C. K. Briggs

May 1988

Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

.S. Energy Flow – 1986
et Primary Resource Consumption 74 Quads

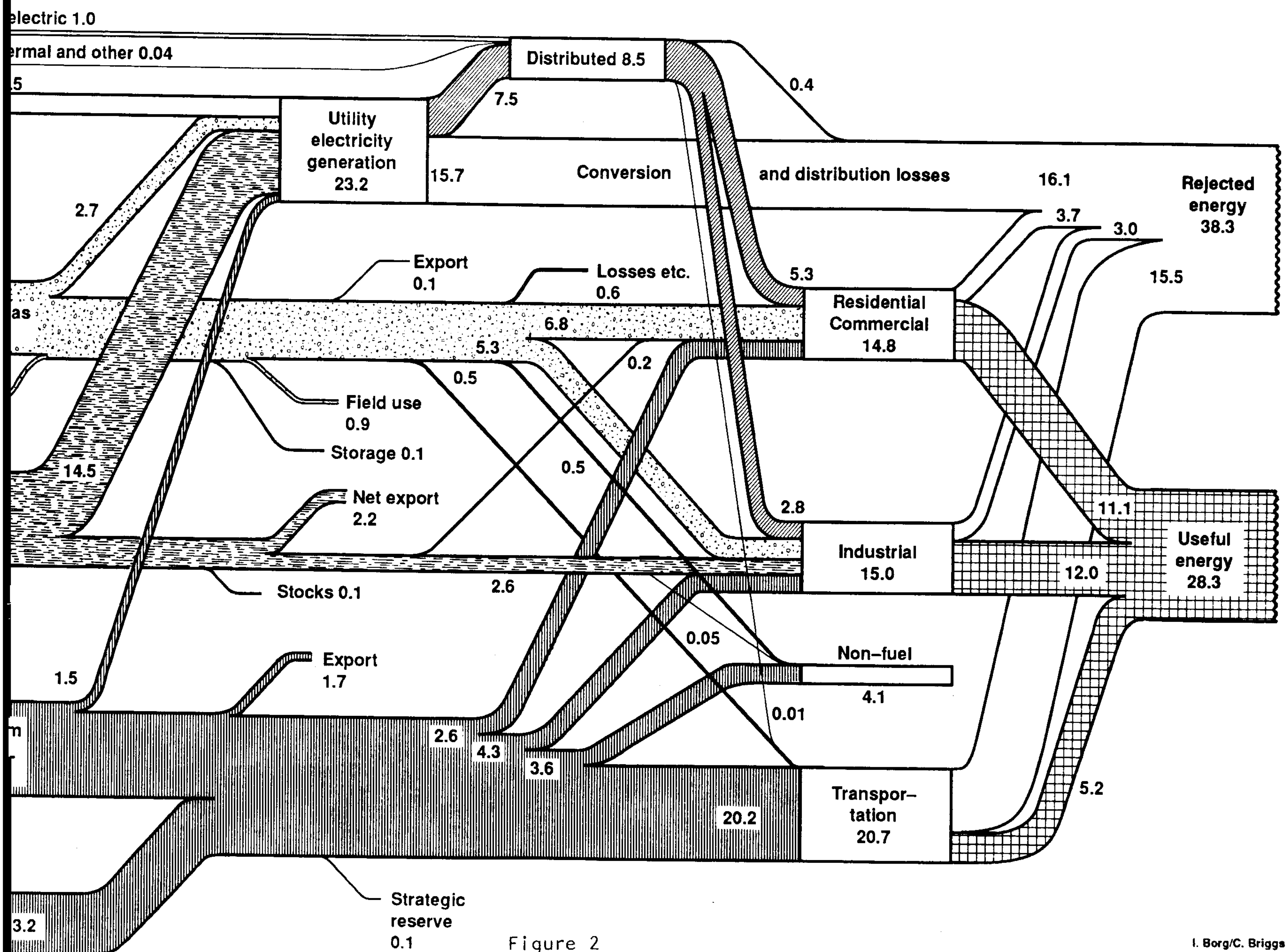


Figure 2

I. Borg/C. Briggs
Revised May '88
FL-014-U-6896-02

Table 1. Comparison of Annual Energy Use in U.S.[4]

	Quads							
	1980	1981	1982	1983	1984	1985	1986	1987
Natural gas	19.91	19.70	18.26	16.53	17.93	16.91	16.47	16.84
Imports	0.99	.90	0.93	0.94	0.86	0.93	0.75	0.99
Crude oil and NGL								
Domestic crude & NGL	20.50	20.45	20.50	20.58	21.12	21.23	20.53	19.82
Foreign imports (incl. products & SPR)	14.67	12.65	10.80	10.66	11.44	10.62	13.21	13.88
Exports	1.17	1.27	1.75	1.58	1.55	1.67	1.68	1.65
SPR storage reserve*	0.10	0.71	0.37	0.49	0.42	0.24	0.11	0.17
Net use (minus exports and SPR)	33.90	31.12	29.18	29.17	30.59	29.94	31.95	31.87
Coal (incl. exports)	18.60	18.38	18.64	17.25	19.72	19.33	19.51	20.12
Electricity								
Hydroelectric (net only)								
Utility	0.94	0.89	1.06	1.13	1.10	0.96	0.99	0.85
Imports	0.22	0.35	0.31	0.37	0.41	0.42	0.37	0.42
Geothermal & other (net only)	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.04
Nuclear	2.74	3.01	3.13	3.20	3.55	4.15	4.48	4.92
Gas	3.81	3.76	3.34	3.00	3.22	3.16	2.70	2.94
Coal	12.12	12.58	12.58	13.21	14.02	14.54	14.44	15.19
Oil	2.63	2.20	1.57	1.54	1.29	1.09	1.45	1.26
Total fuel	22.48	22.81	22.01	22.47	23.62	24.36	24.47	25.62
Total transmitted energy	8.02	8.18	7.96	8.25	8.64	8.85	8.86	9.20
Residential and Commercial	15.08	14.54	14.63	14.40	15.01	14.90	14.83	15.10
Industrial+	23.85	22.54	20.02	19.40	21.06	20.41	20.04	20.57
Transportation	19.67	19.47	19.04	19.11	19.85	20.09	20.74	21.13
Total consumption** (DOE/EIA)	76	74	71	70	73	74	74	76

* Strategic petroleum reserve storage began in October, 1977.

+ Includes field use of natural gas and non-fuel category and excludes electrical losses.

**Note that this total is not the sum of entries above.

THE U.S. ECONOMY IN 1987

Growth in the gross national product (GNP) in 1987 was similar to growth recorded in the preceding two years (Table 2). The amount of energy consumed per unit of GNP continued to decline from its 1970 peak reflecting increased energy efficiency in the industrial sector as well as changes in the mix of products comprising the gross national product (Fig. 3). The value of goods and services (in 1982 dollars) exported in 1987 increased by almost 13% and the value of imports by 7%. While it is reported that net* energy imports were equal in value to 24% of the nation's $153 billion (in 1987 dollars) trade deficit,[6] petroleum and products comprise only 14% of total imports (Table 3). The value of imported automobiles is almost as large as the value of oil imports and in fact in 1985 exceeded the value of oil by a small margin. From Table 3 it can be seen that without these two types of imports totaling $145 billion (1982 dollars), exports would have exceeded imports by $10 billion.

COMPARISON OF ENERGY USE WITH 1986 AND EARLIER YEARS

Total energy use increased in 1987 by less than 3%. All major end-use sectors (residential/commercial, industrial and transportation) experienced growth (Table 1). For almost a decade the demand in the residential/commercial sector has remained relatively stable - approximately 15 quads, and the 1987 increase is small. Industrial energy consumption appears to have stabilized near 20 quads for the last several years. It declined annually between 1980–1984. Transportation use increased for the fifth year in a row. The 1987 increase of 1.8% reflects a greater number of miles driven per vehicle encouraged by low gasoline prices and a greater number of registered automobiles. The latter is influenced by population growth. These increases were partially offset by the improved average efficiency of the automotive fleet.

DEMAND AND SUPPLY OF FOSSIL FUELS

Demand for oil in the economy rose while domestic crude oil production fell for the second year. Both trends relate to the precipitous drop in world oil prices in early 1986 (Fig. 4). Declining U.S. oil reserves and increased reliance on foreign oil prompted

* The U.S. exports some energy commodities which counterbalance energy imports (chiefly crude oil); imports of $44.2 billion less exports of $7.7 billion results in a net energy bill for energy of $36.5 billion (all in 1987 dollars).

Table 2. Economic Indicators: percent change from preceding year[5]
(based on 1982 dollars)

	Year		
	1985	1986	1987
Gross National Product	2.7	2.9	2.9
Personal Consumption Expenditures	3.5	4.2	1.9
Gross Private Domestic Investment	-0.7	2.8	4.9
Export of Goods and Services	-2.0	3.3	12.8
Import of Goods and Services	3.8	10.5	7.3
Government Purchases of Goods and Services	6.8	3.8	2.5

Table 3. Imports and Exports[5]
(billions of 1982 dollars)

	1984	1985	1986	1987(p)
Imports of Goods and Services	453	471	523	561
Petroleum and products	64	60	74	77
Other non-durable goods	87	92	93	103
Automobiles	54	61	66	68
Other durable goods	145	156	182	196
Services	103	102	103	117
Exports of Goods and Services	370	362	377	426
Net trade imbalance	83	109	146	135

(p) = preliminary

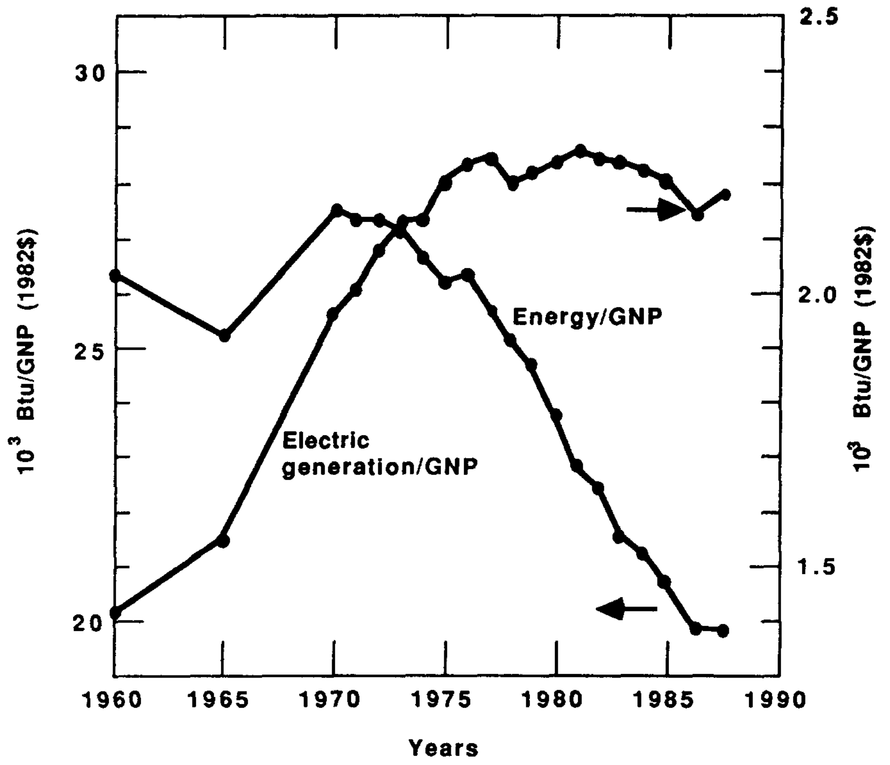
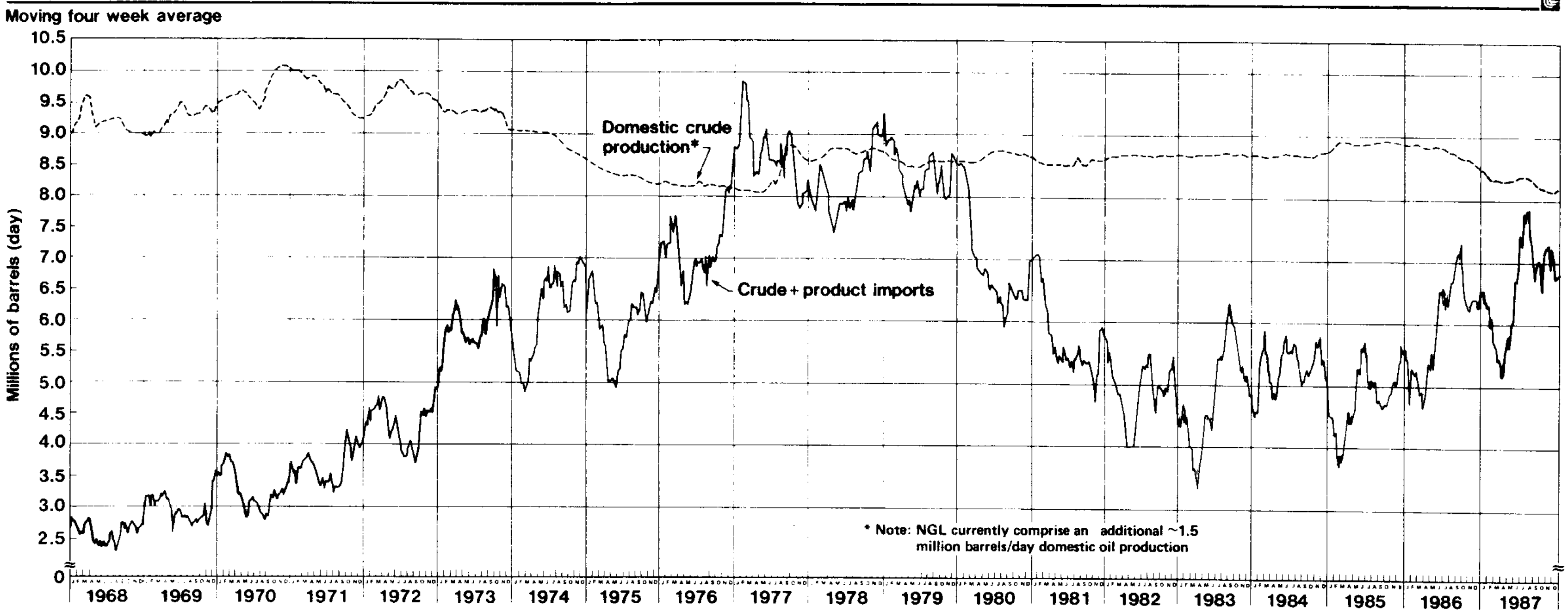


Figure 3. Energy demand and electrical generation per unit of GNP (1982 dollars)

numerous articles with titles such as "The Next Oil Crisis", "America's Looming Energy Crisis", "The Avoidable Oil Crisis", etc. Nonetheless, the U.S. is in a much better position to live with a short-fall than it was in 1973 or 1979. Among the reasons are:

- The source of the crude input to U.S. refineries has changed materially (Fig. 5).
- We no longer rely so heavily on Middle Eastern and African crude suppliers.
- The flexibility of U.S. refineries has increased so as to handle a wider range of crude oils, particularly heavier oils that comprise a large share of Western hemisphere production.

PETROLEUM IMPORTS AND DOMESTIC PRODUCTION



REFINER ACQUISITION COST OF CRUDE OIL

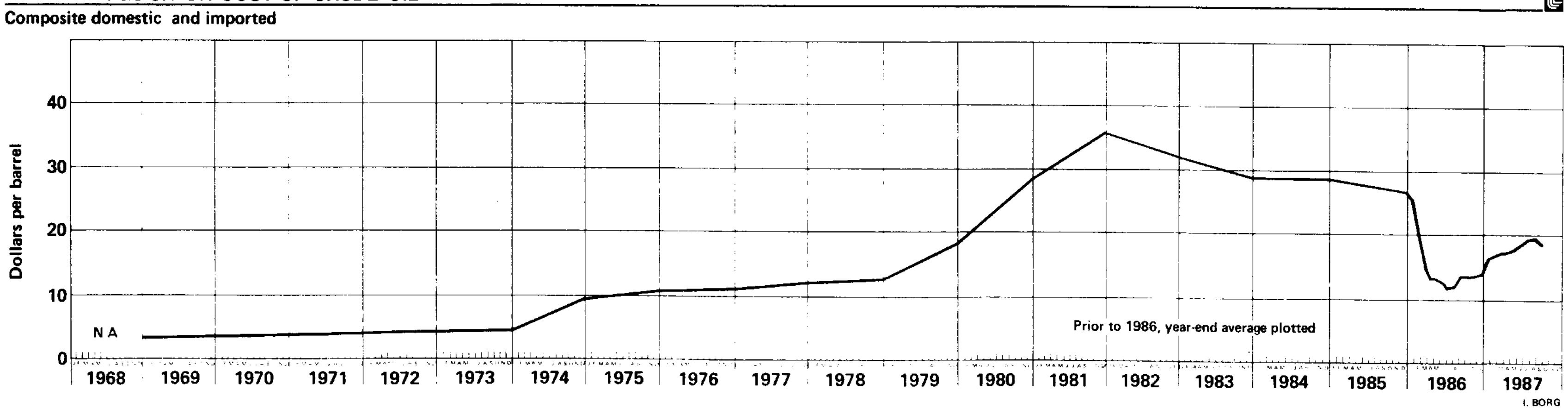


Figure 4

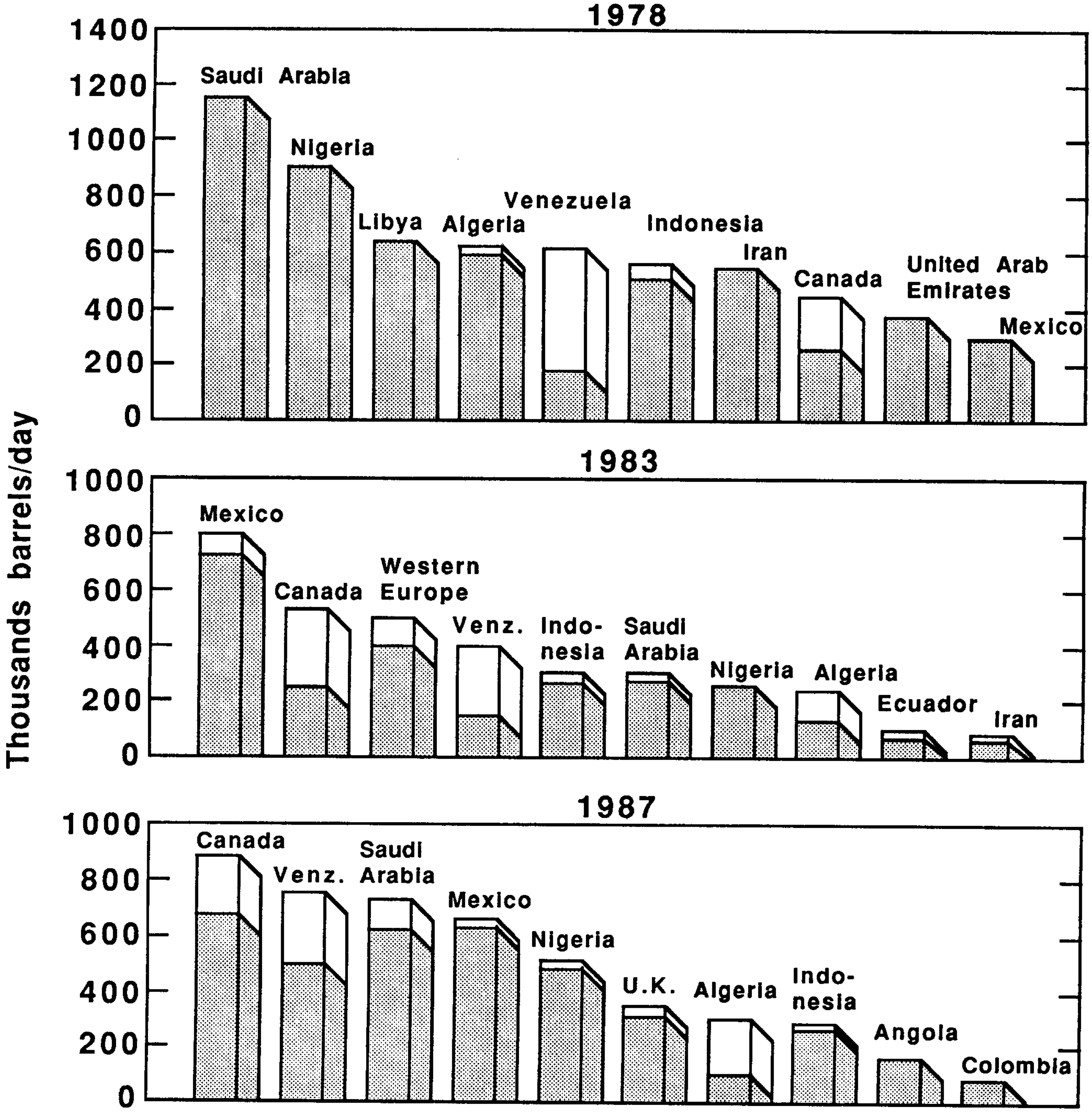


Fig. 5. Ten largest foreign sources of crude oil and petroleum products (exclusive of product imports from Virgin Islands, Bahamas, Trinidad, etc.).

- At year-end the Strategic Petroleum Reserve contained 541 million barrels which is designed to mitigate shortages.

- The electric generation sector has cut its use of oil in half since 1979, and industrial users have installed multi-fueled boilers, so that natural gas is an alternative fuel if needed.

Nonetheless, the U.S. long term oil supply remains of concern since, even with an [redacted]

U.S. ELECTRICAL DEMAND

Electrical sales in 1987 rose by 3.3% (Table 4) thus exceeding projections of growth (Table 5) of many agencies and institutes. Demand in some states such as Massachusetts increased by twice the national average compounding what is anticipated to be regional short-falls in the near future.[8]

Table 4. U.S. Electrical Generation[4]

	Year		
	1985	1986	1987
Total electrical generation (bn kWh)	2469	2489	2571
Nuclear contribution (bn kWh)	384	414	455
Percent nuclear	15.5	16.6	17.7
Installed nuclear capacity (GWe)*	79.4	85.2	93.7
Number of operable reactors	95	100	108**
Annual capacity factor (%)	58.5	56.9	57.4

* Net summer capability of operable reactors.
** An additional 4 reactors are in start-up status.

Contributions to total generation from coal, nuclear and natural gas energy increased; only those from oil and hydropower declined; and the amount related to renewable forms of energy other than hydropower remained at 1985-86 levels. Coal supplied 57% of net electrical generation by utilities and nuclear 18% at year-end.

NUCLEAR POWER

The year was a memorable one for the nuclear power industry. It included many notable events:

- First dismantling of a nuclear power plant, a thirty year-old, 70 MWe reactor (Shippingport, PA).

- Federal Energy Regulatory Commission approval for the conversion of an incompleted nuclear power plant to a gas-fired cogeneration power plant (Midland, MI).

Table 5. Forecasts of Average Annual Growth in Electric Demand (1985–2000)

Forecaster	Year of Forecast	Growth (%)
National Coal Association	1986	2.1
U.S. Department of Commerce	1985	2.4
Edison Electric Institute	1986	2.2
Data Resources	1986	2.6
Gas Research Institute	1987	1.6
Electrical World	1985	2.5
DOE/EIA (Annual Outlook for U.S. Electric Power)	1987	2.6
Applied Energy Service	1985	2.6
Wharton Econometric Forecasting Associates	1985	2.5
DOE (National Energy Policy Plan Projections to 2010)	1986	2.5
National Electrical Manufacturers Association	1986	2.0
Chemical Bank	1984	2.9

Modified and amplified from "Energy Security" Department of Energy Report DOE/S-0057, p. 137, March 1987.

- Bankruptcy of a utility associated with the construction and licensing of a nuclear power plant (Seabrook, NH).
- First order received for a nuclear plant by a U.S. supplier for almost a decade. Subsequently another two manufacturers also received foreign orders.
- The first shut-down of a nuclear facility by NRC for a non-mechanical problem, specifically operators sleeping on the job (Peach Bottom, PA).
- Public vote of confidence for a nuclear plant by referendum (Maine Yankee, ME).

At the beginning of 1987 there were 108 nuclear plants licensed for operation; by year-end there were nine additions* and six deletions from the list which brought the total to 111.[4] Malfunctions of various sorts shut-down a number during the year, e.g., Davis-Besse, OH; North Anna 2, VA; Ferme 2, MI; and Washington Public Power Supply System Plant 2, WA. Other plants shut down in earlier years such as Rancho Seco, CA; Pilgrim, MA; Sequoyah 1 & 2, TN; and Fort Vrain, CO, were still under repair.

In recent years a few nuclear plants have been put on line at reasonable cost per kilowatt of generating capacity, e.g., Duke Power's Catawba 2 in North Carolina at $1600 per kilowatt;[9] however, costs typically are much higher. The spectre of cost overruns during construction, licensing delays and unwillingness of public utility commissions to allow utilities to pass on the total cost of the plants to rate payers have profoundly affected policies and plans of the nation's utilities. Examples of plants whose costs have substantially increased because of corrective actions of numerous sorts include twin nuclear reactors (2-1075 MWe) at Diablo Canyon, CA, Nine Mile Point 2, NY (1080 MWe), Plant Vogtle, GA (2-1160 MWe), Comanche Peak, TX (2-1110 MWe) and Seabrook, NH (1150 MWe).

In the case of Diablo Canyon, the Public Staff Division, a branch of the California Public Utilities Commission, has recommended that the Pacific Gas and Electric Co. be allowed to recover only $1.15 billion or about 20% of the $5.8 billion cost ($2700 per kw of generating capacity) on the grounds of mismanagement and negligence on the part of the utility.

In order to avoid further delay in receiving return on their investment, Niagara Mohawk and other utility partners struck an agreement with the New York Public Service Commission to absorb $2.1 billion of the $6.3 billion ($5830 per kw) for Nine Mile Point 2. The utilities' shareholders have seen their stocks fall and bond ratings lowered in anticipation of the large write-offs about to be taken by the utilities.

---

* Palo Verde 3, AZ; Nine Mile Island 2, NY; Plant Vogtle I, GA; Byron 2, IL; Clinton 1, IL; Shearon Harris 1, NC; Bear Valley 2, PA; Braidwood 1, IL; and South Texas Project 1, TX.

Georgia Power Co., principal owner of Plant Vogtle I (1160 MWe) may receive only 84% of the $6.1 billion requested for construction and financing of the first of two reactors now operating because of alleged imprudence on the part of the utility.[9] The final cost of the two reactors is estimated to be $8.87 billion or $3825 per kw.

A similar situation is evolving at Comanche Peak where cost estimates have escalated to $9.1 billion ($3950 per kw), and bond-rating companies have placed owner Texas Utilities Electric Co.'s stock on a credit review list.[10]

The bankruptcy of the Public Service Company of New Hampshire because of its inability to pay interest on debts incurred during construction of the Seabrook nuclear plant shook the utility industry. This in turn was due to slowness of the licensing of the plant and public opposition to both the plant and anticipated rate increases associated with its licensing. Ironically, New Hampshire Governor John Sununu believes that because of the bankruptcy the licensing is "virtually a certainty".[11] Furthermore, he hazarded a guess that the legal fees associated with the bankruptcy would exceed the amount of money needed to prevent it.

Independent of whether a proposed power plant burns nuclear or fossil fuels, the risks and capital costs have escalated so that building a large (1000 MW) base-load plant is almost beyond many utilities' ability to finance. Not surprisingly utilities and their traditional engineering contractors are looking into smaller generating units of all types to supply the power needed to keep reserve margins at acceptable levels in the next several decades. The combination of even modest annual increase in demand for electric power and retirement of generating plants within the next decade will more than offset new capacity currently under construction (Fig. 6). The need will be mitigated by improvements in utility inter-ties, construction of cogeneration plants by the private sector, and possible increased power imports from Canada. Thus in the view of most observers, in order that new base-load capacity be available when needed, decisions, plans and orders with suppliers must be formulated by the nation's utilities within a few years.

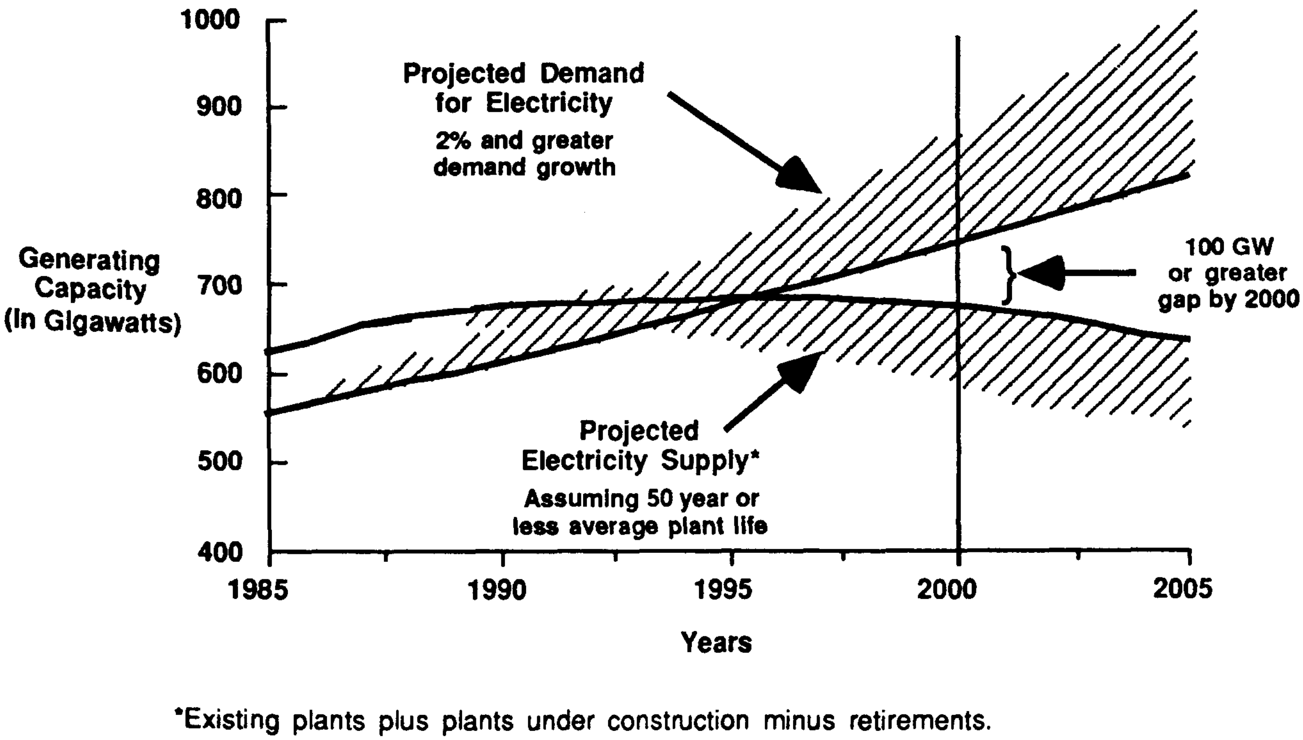


Figure 6. Department of Energy's project of electrical demand and supply to 2005. Source: "Energy Security", DOE/S-0057, p. 139, March 1987.

NON-UTILITY ELECTRIC POWER PRODUCTION

Electrical generation by non-utilities represents about 4 percent of the U.S. total according to the Edison Electric Institute, the electric utility trade group.[12] By its nature the exact contribution to the whole cannot be known precisely since small generators are largely unregulated and consume some fraction of the power they produce. About 80% of non-utility generation is power produced by cogenerators.[13,14] Non-utility generators are often divided into two groups: so-called qualified facilities* (QF) under the Public Utility Regulatory Policies Act

* Qualified facilities include small power producers fueled by renewable energy sources and cogenerators meeting certain efficiency standards.

of 1978 (PURPA) and facilities that do not qualify. The latter sell their power to utilities at market rates whereas the qualified facilities sell at "avoided costs" set by the individual state regulatory bodies.

Non-utility generation has shown the fastest growth in three regions: California, Texas, and New England. In California the reasons relate to the advantages of cogeneration in the canning, refining and oil industries as well as to the high rates paid by the utilities for the power, up until recently, under the California Public Utilities Commission rulings. In Texas the refining and petrochemical industries made widespread use of cogeneration in their operations. New England's non-utility production is centered on the wood-burning industry and the region's traditional reliance on small hydroelectric dams for local power.

Growth in non-utility generation continued in 1987; however, it was not as rapid as in 1986. Many utilities continued to chafe at the consequences of its introduction into the power-mix. In some states the rates paid for the power were so high as to be unreasonable in their view. Another complaint was that cogenerators tend to operate 24 hours a day and do not meet load demands which have diurnal and seasonal fluctuations. Because cogenerators have no obligation to sell to the utilities, their reliability in times for crisis (storms, disasters, etc.) is questioned. The Pacific Gas and Electric Co. relates the story of a 1982 San Francisco, CA, power failure at which time all ten cogenerators on their system disconnected from the system either automatically or on purpose.[12] Probably the most commonly mentioned concern has to do with loss of large customers which tends to raise rates for others on the system. In turn, this encourages the remaining large users to also look to cogeneration. This dilemma has been addressed by the utility commissions who have lowered the rates for large customers as well as the rates utilities must pay cogenerators for electricity generated. Both rate changes tend to make the cogeneration option less attractive. A more general criticism of cogeneration is that the largest share of cogenerators use natural gas as a fuel, which is both a depletable resource and a premium fossil fuel.

Increasingly large utilities are entering the cogeneration business through provisions of PURPA which allow a utility to own a minority share in a qualified facility. Examples include Florida Power and Light Company, Atlantic City Electric Company, Dominion Resources, Inc., the parent of the Virginia Electric Power Company and Pacific Gas and Electric Co. Several states already require QF's to bid competitively to supply utilities with power as contrasted to the usual rate making by state regulatory bodies. Federal regulators plan to promote bidding procedures for all non-utility generators; however compliance will be at the option of the states.

Changes proposed by the Federal Energy Regulatory Commission promise to encourage construction of non-regulated power producing plants. Assuming that independent electric power stations become common, utilities will be relieved of the risks associated with building power plants in a regulated environment. Until further changes are made in FERC rules related to access to long distance transmission lines and associated costs, independent producers are likely to plan and build small plants servicing local areas rather than gigawatt plants selling to more than one region or state. Changes in the offing will take decades to affect materially the existing regulated utility system, but they are already underway.

APPENDIX

Data and Conventions Used in Construction of Energy Flow Charts

Data for the flow chart were provided by tables in the Department of Energy Monthly Energy Review, DOE/EIA-0035,[4] the 1987 Annual Energy Review[15] and the Quarterly Coal Report.[16]

The residential and commercial sector consists of housing units, non-manufacturing business establishments, health and education institutions, and government office buildings. The industrial sector is made up of construction, manufacturing, agriculture, and mining establishments. The transportation sector combines private and public passenger and freight transportation and government transportation including military operations.

Utility electricity generation includes power sold by both privately and publicly owned companies. The non-fuel category of end-use consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feedstocks such as ethane, liquid petroleum gases, lubricants, petroleum coke, waxes, carbon black and crude tar. Coking coal traditionally is not included.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75 percent efficiency was assumed which is a weighted average between space heating at approximately 60 percent and electrical lighting and other electrical uses at about 90 percent. Eighty percent efficiency was assumed in the industrial end-use sector and 25 percent in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

There are some minor differences between total energy consumption shown here in the energy flow charts and the DOE/EIA totals given in Table 1. We use net hydroelectric power in flow charts rather than the gross amount, which is customarily included in DOE/EIA totals. The net figure is calculated from the total number of kilowatt hours produced by hydroelectric sources. Thus the sum of individual contributions to annual energy consumption shown in the energy flow charts will be smaller by several quads (10^{15}btu) than total published by DOE/EIA and given at the top of the charts and in Table 1.

Conversion Factors

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

Fuel	Energy Content (Btu)
Short ton of coal	22,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,000
Kilowatt hour of electricity	3,400

More detailed conversion factors are given in the Department of Energy's Monthly Energy Review.

REFERENCES

1. A. L. Austin, Energy Distribution Patterns in the U.S.A. for 1970 and 1985, Lawrence Livermore National Laboratory Report UCID-16022 (1972).

2. I. Y. Borg, Energy-Flow Diagrams: An LLNL Contribution to Energy Analysis, Lawrence Livermore National Laboratory Report MISC-4500 (October 1987).

3. C. K. Briggs and I. Y. Borg, U.S. Energy Flow - 1986, Lawrence Livermore National Laboratory Report UCID-19227-86 (August 18, 1987).

4. Monthly Energy Review, DOE/EIA-0035(87/12) (March 1988).

5. Survey of Current Business, U.S. Department of Commerce/Bureau of Economic Analysis (February 1988).

6. Energy's Share of the Trade Deficit, Energy Daily 50, 4, (March 16, 1988).

7. "Wyoming Coal Makes History as it Heads for Taiwan", Denver Post, February 21, 1988, p. 3G.

8. R. E. Curtis, "Time is Running Out For An Energy Solution", Boston Globe, November 3, 1987.

9. J. F. Ahearne, High Costs, Lower Demand Plague U.S. Nuclear Industry, Resources No. 88, 5-8 (Summer 1987).

10. D. Real, "Comanche Peak Pricetag to Increase by $1.5 Billion", The Dallas Morning News, March 19, 1988, p. 1A.

11. A. Freudmann, Seabrook Will be Licensed, Sununu says, Energy Daily 16, 1 (March 30, 1988).

12. A. Pollack, "Non-utility Electricity Rising", The New York Times, August 12, 1987, p. D-1.

13. Questions Seen for U.S. Cogeneration, Oil and Gas J., 86, 21 (January 18, 1988).

14. M. J. Dodman, Electric Utilities Face Increased Competition, Resources No. 90, 20-22 (Winter 1988).

15. Annual Energy Review 1987, DOE/EIA-0384(87) (May 1988).

16. Quarterly Coal Report, DOE/EIA-0121(87/4Q), Table 31 (May 1988).

Technical Information Department · Lawrence Livermore National Laboratory
University of California · Livermore, California 94550

ENERGY PROGRAM REPORT

UCID-19227-87

U.S. ENERGY FLOW - 1987

I. Y. Borg

C. K. Briggs

May 1988

Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

DISCLAIMER

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price Code	Page Range
A01	Microfiche
Papercopy Prices	
A02	001 - 050
A03	051 - 100
A04	101 - 200
A05	201 - 300
A06	301 - 400
A07	401 - 500
A08	501 - 600
A09	601

ABSTRACT

Energy use in 1987 increased by 3%. All end-use sectors experienced modest growth including transportation which increased for the fifth consecutive year despite improved average mileage of the automotive fleet. Oil imports increased again in 1987 while domestic crude oil production declined. The value of gross imports of crude oil and petroleum products (in 1982 dollars) comprised 14% of total U.S. imports of durable and non-durable goods in both 1986 and 1987.

Electrical sales rose by 3.3% thus exceeding projections of almost all forecasters. Non-utility generation of power, some of which is sold to the utilities by cogenerators, contributed about 4% to the whole; however it is completely assessed since some or all of the power is used by the self-generators themselves. Regulatory changes under discussion in 1987, anticipated regional shortages, and the inability of many utilities to finance large base-load plants promise to encourage the growth of non-utility generation in the next decade.

INTRODUCTION

United States energy flow charts tracing primary resource supply and end-use have been prepared by members of the Energy Program and Planning groups at the Lawrence Livermore National Laboratory since 1972.[1,2] They are convenient graphical devices to show relative size of energy sources and end-uses since all fuels are compared on a common btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

ENERGY FLOW CHARTS

Figure 1 and 2 are energy flow charts for calendar years 1987 and 1986[3] respectively. The 1987 charts are based on provisional data published by the Energy Information Administration of the Department of Energy. Conventions and conversion factors used in the construction of the charts are given in the Appendix. For comparison with earlier years, consumption of energy resources is given in Table 1. These data in many instances contain revisions of data initially published by the Department of Energy.

U.S. Energy Flow – 1987
Net Primary Resource Consumption 76 Quads

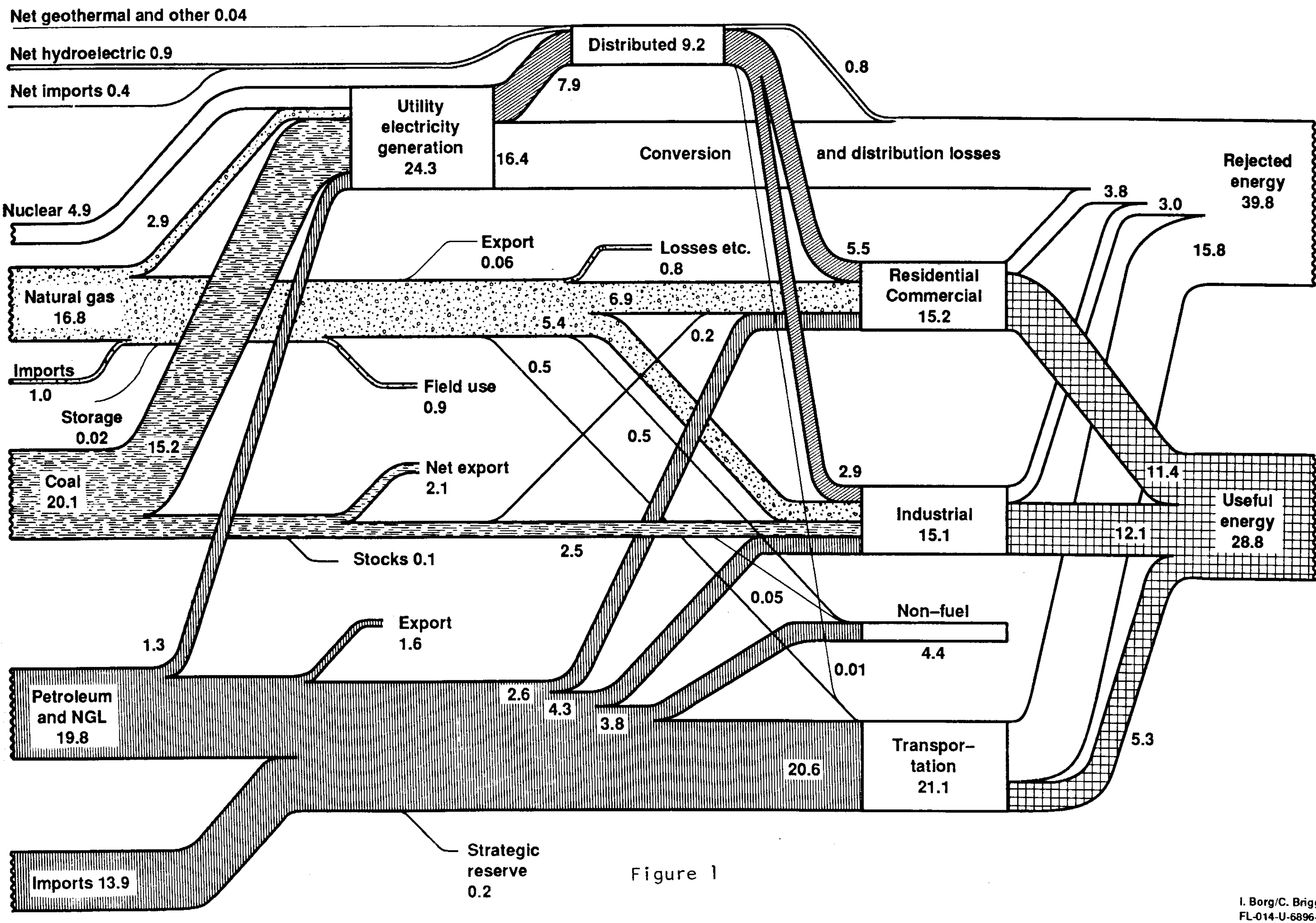


Figure 1

I. Borg/C. Briggs
FL-014-U-6896-01

UCID-19227-88

U.S. ENERGY FLOW - 1988

I. Y. Borg
C. K. Briggs

June 1989

Lawrence Livermore National Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.
Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

This report has been reproduced
directly from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information
P.O. Box 62, Oak Ridge, TN 37831
Prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.,
Springfield, VA 22161

Price Code	Page Range
A01	Microfiche
Papercopy Prices	
A02	001–050
A03	051–100
A04	101–200
A05	201–300
A06	301–400
A07	401–500
A08	501–600
A09	601

ABSTRACT

Trends in energy supply and use that were established in the mid-80's continued into 1988. Oil remains the largest single source of energy for the country. Overall energy consumption increased in all end-use sectors; however the greatest growth occurred in residential/commercial sectors; electrical demand increased three percent; the use of coal particularly for electrical generation increased for the eighth year; domestic oil production declined and oil imports increased; and increases in use of transportation fuels more than offset fuel economies effected by fuel standards imposed on new passenger cars since 1978. Most of the trends are a reflection on the decline in cost of all fossil fuels led by the precipitous fall of crude oil prices in the spring of 1986. During 1988 natural gas prices remained depressed and increased use would have been larger in central and northeastern sectors of the country if pipelines from western U.S. and Canada could have handled larger volumes.

INTRODUCTION

United States energy flow charts tracing primary resource supply and end-use have been prepared by members of the Energy Program and Planning groups at the Lawrence Livermore National Laboratory since 1972[1,2]. They are convenient graphical devices to show relative size of energy sources and end-uses since all fuels are compared on a common Btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

ENERGY FLOW CHARTS

Figure 1 and 2 are energy flow charts for calendar years 1988 and 1987[3] respectively. The 1988 chart is based on provision data published by the Energy Information Administration of the Department of Energy. Conventions and conversion factors used in the construction of the charts are given in the Appendix. For comparison with earlier years, consumption of energy resources is given in Table 1. These data in many instances contain revisions of data initially published by the Department of Energy.

U.S. Energy Flow – 1988
Net Primary Resource Consumption 78 Quads

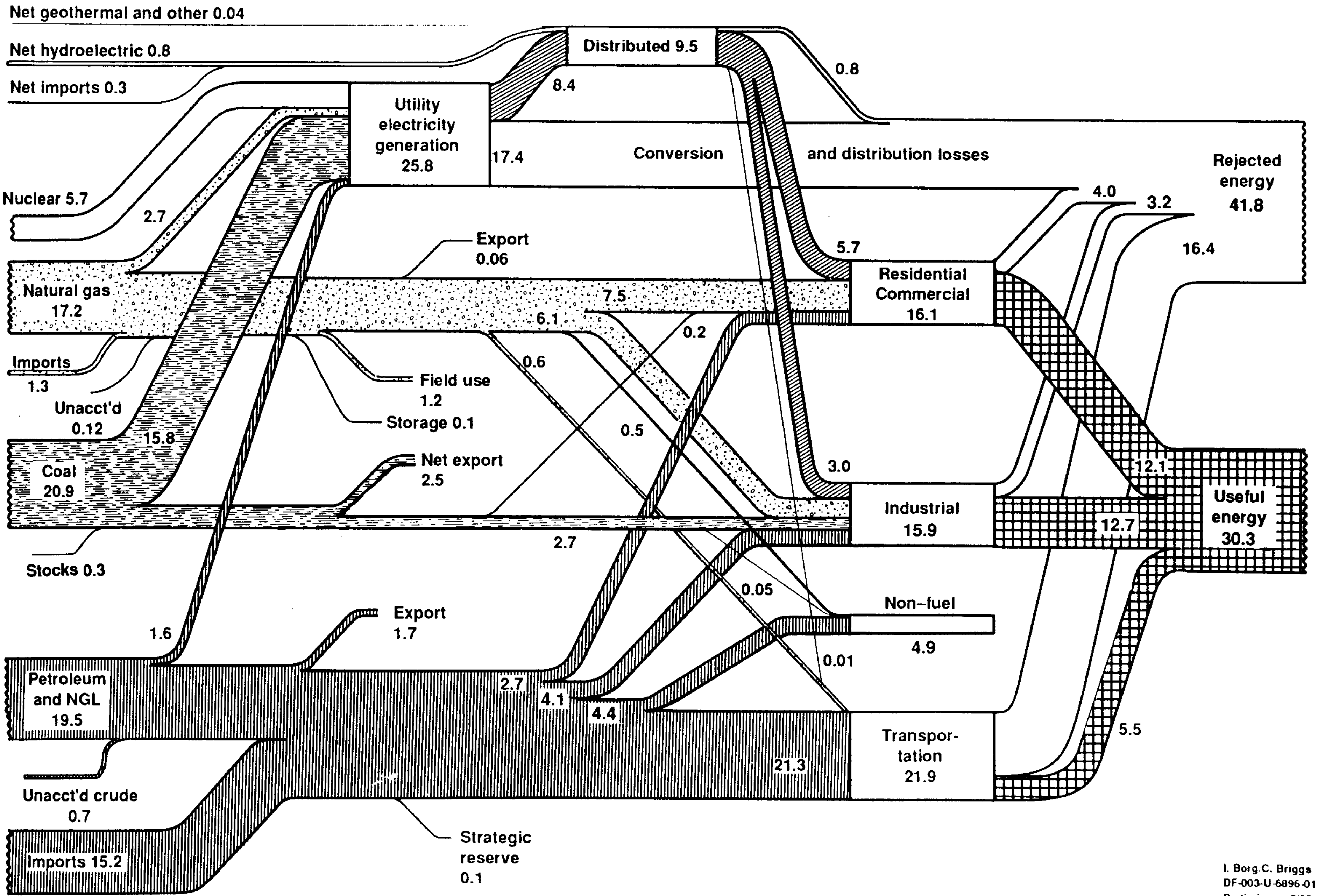


Figure 1

nergy Flow – 1987
mary Resource Consumption 76 Quads

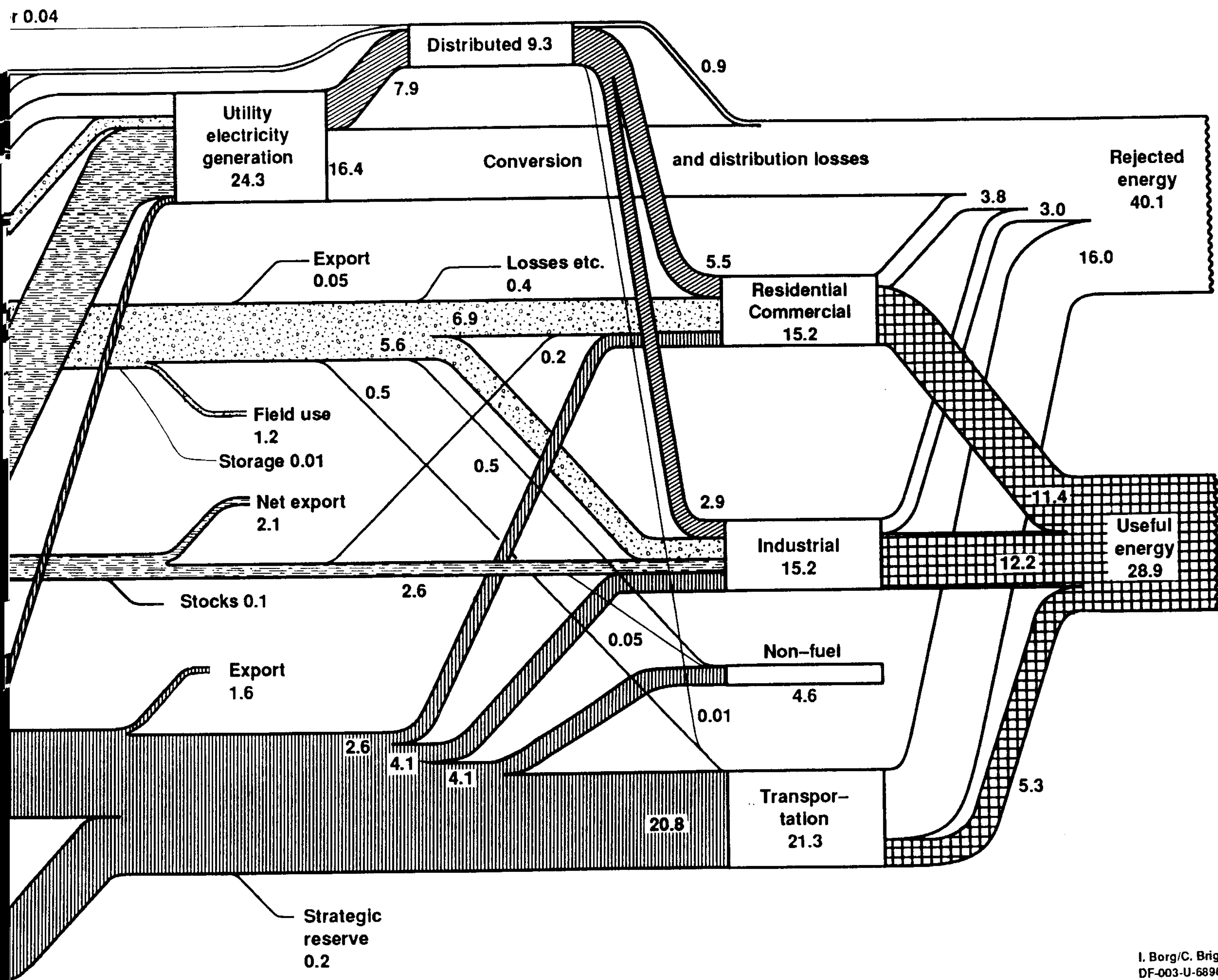


Figure 2

I. Borg/C. Briggs
DF-003-U-6896-01
Revised 6/89

Table 1. Comparison of Annual Energy Use in U.S.[4]

	Quads							
	1981	1982	1983	1984	1985	1986	1987	1988
Natural gas production	19.70	18.26	16.53	17.93	16.91	16.47	17.05	17.19
Imports	0.90	0.93	0.94	0.86	0.93	0.75	0.99	1.28
Crude oil and NGL								
Domestic crude & NGL	20.45	20.50	20.58	21.12	21.23	20.53	19.89	19.52
Foreign imports (incl. products & SPR)	12.65	10.80	10.66	11.44	10.62	13.21	14.18	15.15
Exports	1.27	1.75	1.58	1.55	1.67	1.68	1.63	1.75
SPR storage reserve*	0.71	0.37	0.49	0.42	0.24	0.11	0.17	0.11
Net use (minus exports and SPR)	31.12	29.18	29.17	30.59	29.94	31.95	32.27	32.81
Coal production (incl. exports)	18.38	18.64	17.25	19.72	19.33	19.51	20.12	20.94
Electricity								
Hydroelectric (net)								
Utility	0.89	1.06	1.13	1.10	0.96	0.99	0.85	0.76
Imports	0.35	0.31	0.37	0.41	0.42	0.37	0.48	0.30
Geothermal & other (net)	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04
Nuclear (gross)	3.01	3.13	3.20	3.55	4.15	4.48	4.92	5.68
Fossil Fuel (gross)	18.54	17.49	17.75	18.53	18.79	18.59	19.37	20.12
Gas	3.76	3.34	3.00	3.22	3.16	2.70	2.94	2.72
Coal	12.58	12.58	13.21	14.02	14.54	14.44	15.17	15.84
Oil	2.20	1.57	1.54	1.29	1.09	1.45	1.26	1.56
Total transmitted energy	8.18	7.96	8.25	8.64	8.85	8.86	9.25	9.51
Residential and Commercial	14.54	14.63	14.40	15.01	14.90	14.83	15.20	16.14
Industrial+	22.54	20.02	19.40	21.06	20.41	20.04	21.01	22.04
Transportation	19.47	19.04	19.11	19.85	20.09	20.74	21.35	21.83
Total consumption** (DOE/EIA)	74	71	70	73	74	74	77	80

* Strategic petroleum reserve storage began in October, 1977.

\+ Includes field use of natural gas and non-fuel category and excludes electrical losses.

** Note that this total is not the sum of entries above.

COMPARISON OF ENERGY USE WITH 1987 AND EARLIER YEARS

For the second year in a row, total energy use in the U.S. increased 4%. Increases were experienced in all end-use sectors (Table 1) with the residential/commercial sector recording the largest on a percentage basis. In the cases of both the residential/commercial and industrial sectors the increase in usage was associated with an increase in the use of natural gas. The industrial sector, despite its slightly greater energy usage, remained below historical levels (Figure 3). The break in the upward trend in industrial usage starting in the early seventies reflects the changing makeup and output of the sector and increased efficiency in many processes used. The metal and mining industries and many energy-intensive segments of U.S. industry such as cement and nitrogenous fertilizers have retrenched with a concomitant increased reliance on imports. Nonetheless, the gross national product (GNP) grew almost 4% in 1988 as compared to 3% in 1986 and 1987. Starting in 1975 services contributed more than goods to the GNP (Figure 4), which is reflected to some degree in the declining amount of energy used associated with a unit of GNP.

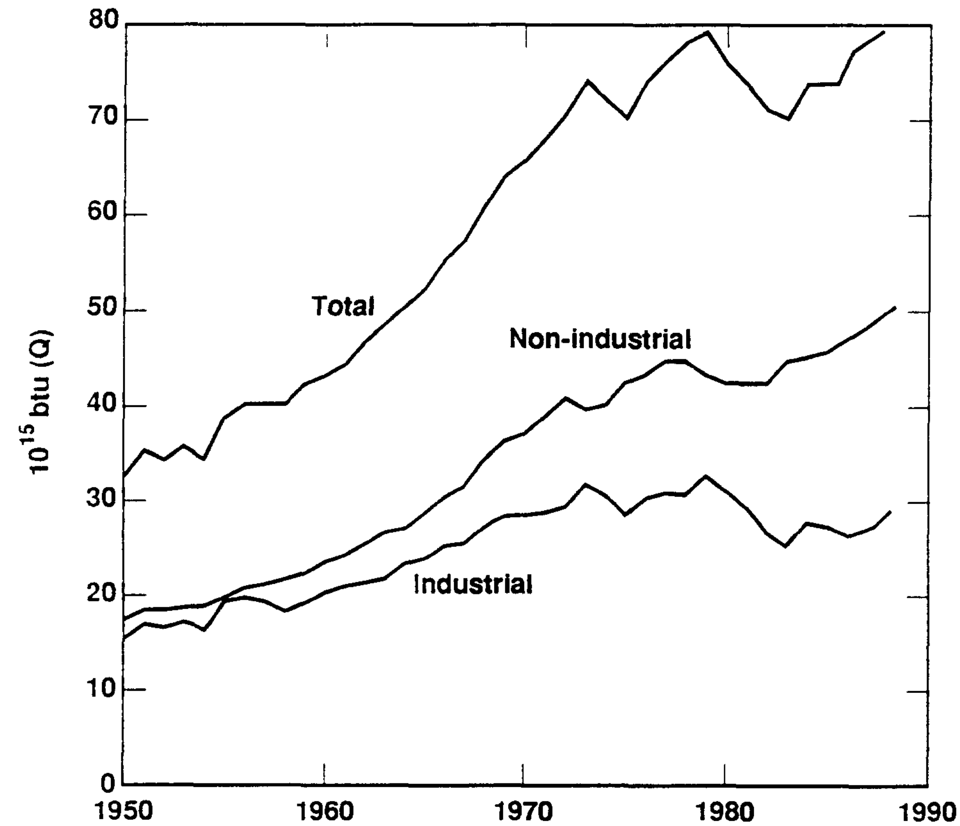


Figure 3. Energy use in U.S.[12]

Source: Annual Energy Review, 1988, DOE/EIA
Gross electrical use is plotted.

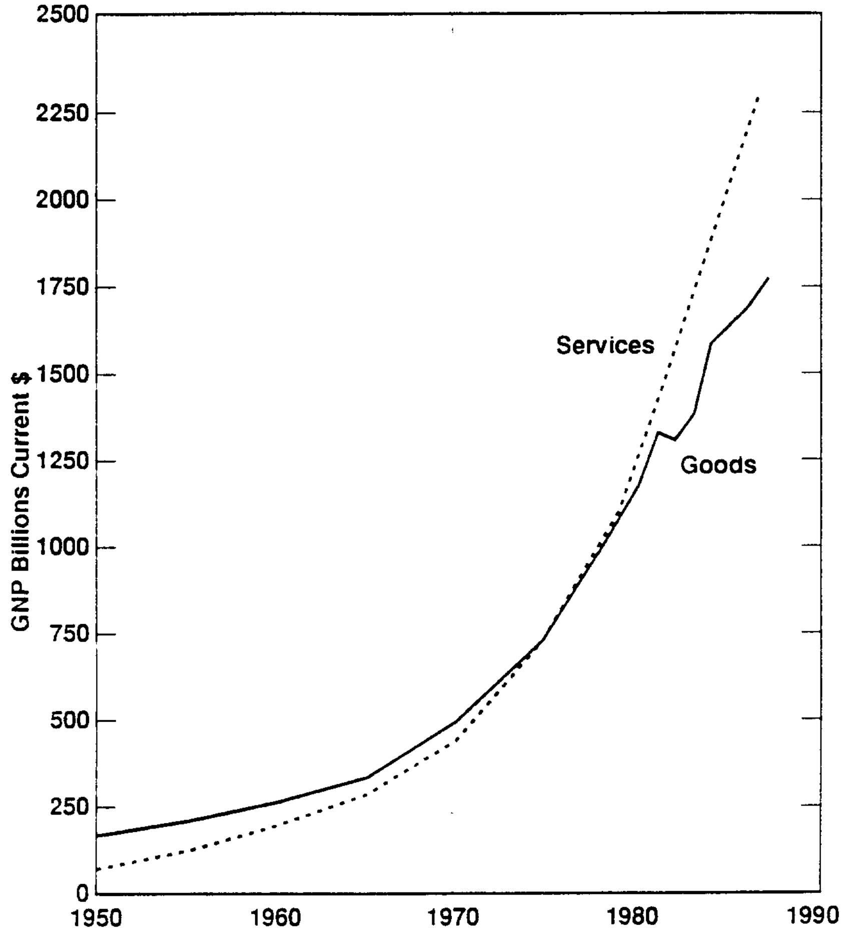


Figure 4. Components of U.S. Gross National Product
Source: Statistical Abstracts, 1989, U.S. Department of Commerce, p.410

Use of energy for transportation rose for the sixth year due to a combination of forces which more than compensated for overall improvements in fleet mileage (Figure 5). Althougn the Corporate Average Fuel Economy (CAFE) standards for new passenger cars remained at 26 miles per gallon in 1988, elimination of older, less efficient vehicles from cars on the road should result in improved mileage overall. The average mileage for all vehicles (passenger cars, trucks, buses, motorcycles, etc.) on the road in 1986, the last year for which data are available, was 14.7 miles per gallon, an improvement of 2.6 miles per gallon in the previous ten years. Over the same time span improvements for passenger cars on the road was 4.8 miles per gallon. Part of the explanation for the small improvement for the total fleet is the increasing popularity of small trucks, vans and off-road vehicles which account for a larger number of miles driven per year. Another contributing factor is that older vehicles with lower efficiency have not been retired rapidly. This in turn reflects the relatively small portion of costs associated with owning and operating a vehicle that motor fuels comprise.

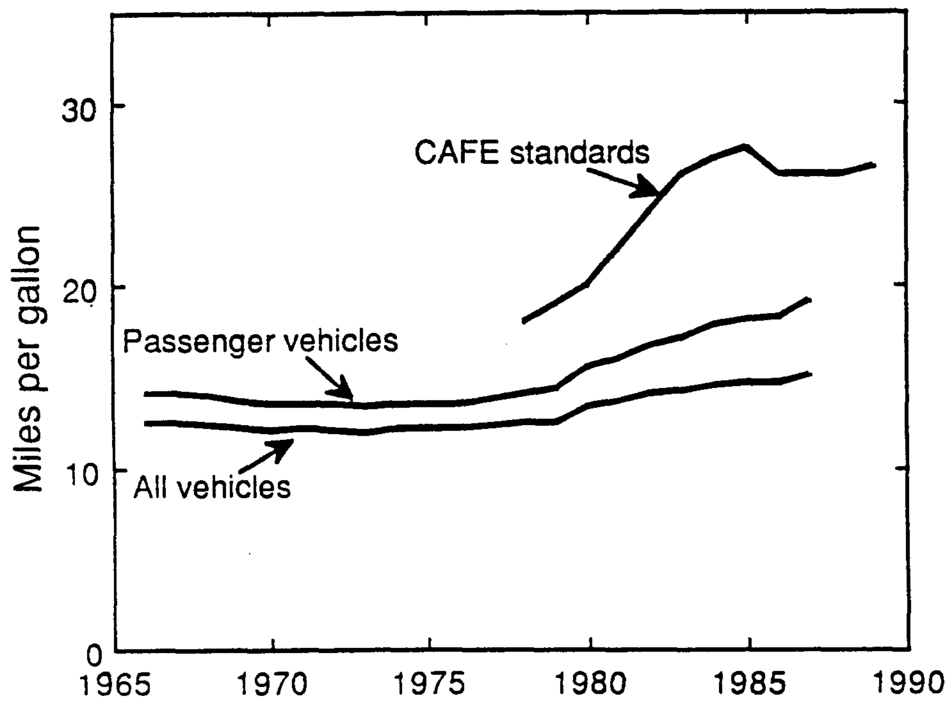


Figure 5.

Source: Annual Energy Review 1987, DOE/EIA, Table 22, p.53

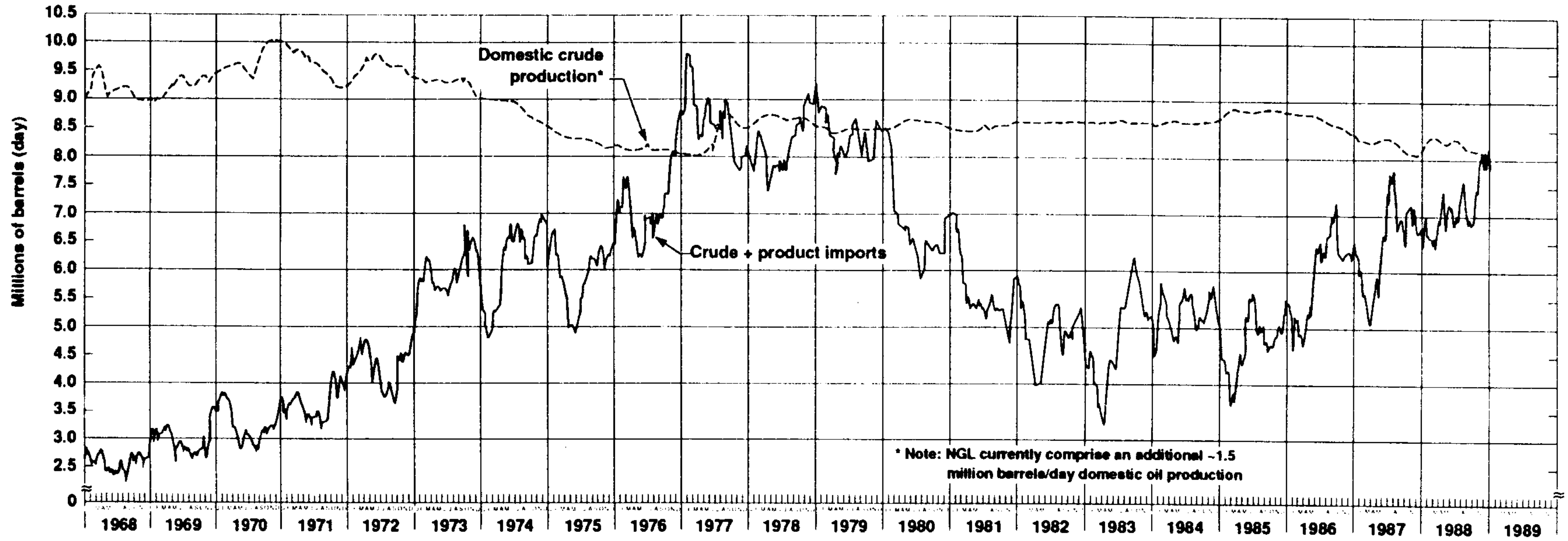
DEMAND AND SUPPLY OF FOSSIL FUELS

Use of all fossil fuels increased in 1988 with coal registering the largest increase (4.5%) due to increased demand for electrical generation. Coal exports were the highest they have been since 1982; increases were registered in both metallurgical and steam coals. Although a price gap between U. S. coals and coal from many other exporting countries is a damper on continued growth in exports, other considerations, particularly security of supply and reliability have made U.S. coals marketable. In 1988 China was unable to deliver on several export contracts because of transportation problems. Australia suffered labor problems, and Colombia in addition to having labor difficulties saw political unrest that interfered with trade.

Continued low world oil prices relative to historical highs at the start of the decade both depressed domestic production and encouraged increased oil imports (Figure 6). At year-end foreign imports comprised approximately 44% of oil supply. Non-OPEC sources of crude oil

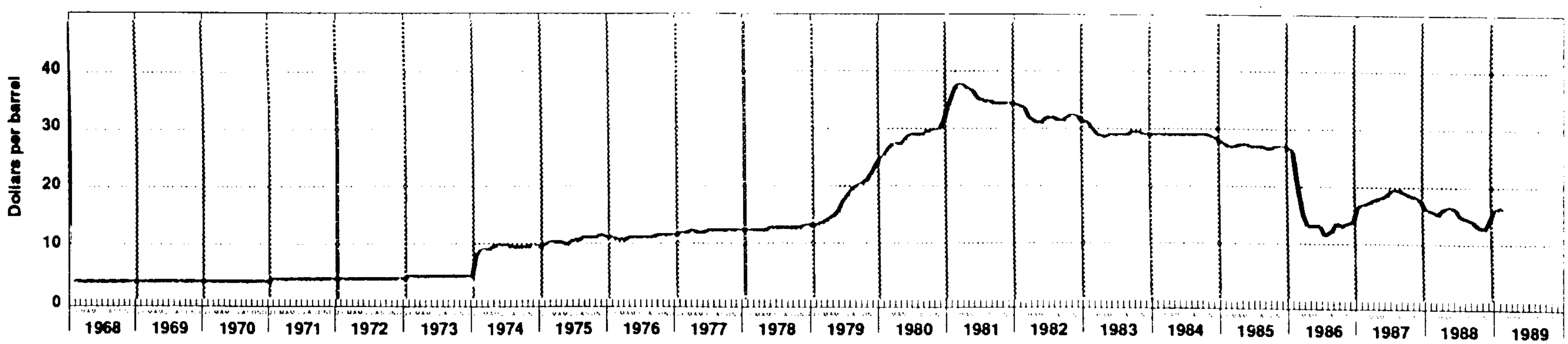
PETROLEUM IMPORTS AND DOMESTIC PRODUCTION

Moving four week average



REFINER ACQUISITION COST OF CRUDE OIL

Composite domestic and imported



I BORG

Figure 6

and products exceeded OPEC sources by less than ten percent. This is in contrast to 1985 when non-OPEC producers supplied 44% more than OPEC producers to the U.S. In 1988 the largest exporter to the U.S. was Saudi Arabia followed by Canada and Mexico whereas in 1985 Saudi Arabian oil was eighth in the list of largest exporters to the U.S.

Natural gas imports from Canada increased 28% over 1987 breaking the previous record set in 1973. Canadian imports comprise about 7% of U.S. supply. The largest growth in demand was shown in the Midwest. Because of the growing desirability of natural gas in the eyes of state and federal legislators, Canadian imports are expected to increase in the coming years; however limitation in pipeline capacity may curb rapid growth[5]. Numerous pipeline proposals were before Canada's National Energy Board at year-end. Also working against a move to substantial increase in the use of gas in the U.S. in the near future are low prices in both the U.S. and Canada, which inhibit replacement of reserves. In 1988 the average U.S. field acquisition price for natural gas was $1.83/million Btu and $2.06/million Btu for imports - less than half the price that prevailed between 1980 and 1984[6]. All exploration indicators (gas well completions, seismic crews and number of rigs operating) were at or near historical lows in 1988[7].

U.S. ELECTRICAL SUPPLY AND DEMAND

Generation by utilities (including hydropower) grew by five percent and exceeded all projections[8]. As conversion and distribution losses are approximately 67%, the growth in actual usage is proportionately smaller; thus consumption increase in principal end-use sectors was approximately 3.5%.

Non-utility generation continued to grow in the U.S. In 1988 it contributed 138.9 billion kWh of additional electricity[9]. Of this total only 56.8 GWh was sold to utilities although three quarters of total non-utility capacity was interconnected to utilities[10]. Thirty-eight percent of the non-utility generators used natural gas, non-fossil fuels [biomass, wood, waste, hydropower, etc.] (41%), coal (20%), and oil (1%) made up the remainder.

Coal remains the nation's largest fuel for power production. It constituted 57% of total fuels in 1987 and 1988. Nuclear power (19.5%) is the second and natural gas (9.4%) the third largest source (Figure 7). Use of natural gas was at 1986 levels, which is far below historical use in the seventies when it was on a par with petroleum. In 1988 hydroelectric contribution to total power generation fell due to low rainfall in critical areas. The shortfall due to low hydroelectric contributions as well as due to increased demand was met by additional coal-fired and nuclear generation.

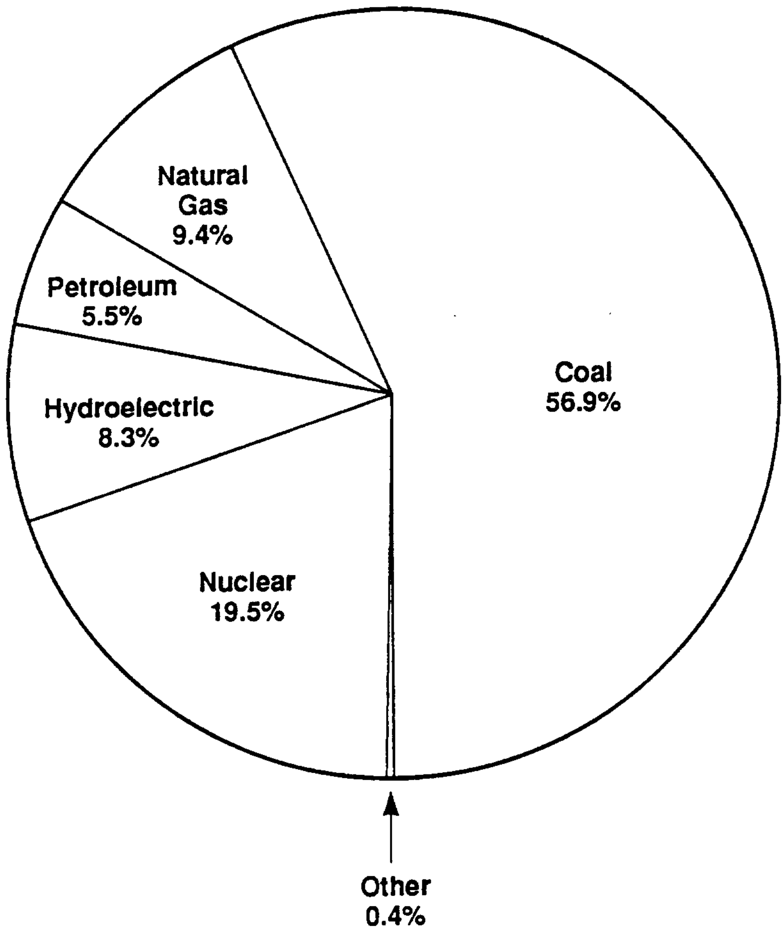


Figure 7. Fuels for U.S. electrical generation
Source: Monthly Energy Review, DOE/EIA-0035(89/1) Table 7.1

NUCLEAR POWER

Controversy concerning the wisdom of operating nuclear reactors continued unabated in 1988. The licensing of the two most contested reactors, Seabrook in New Hampshire and Shoreham in New York, crept forward with the imminent issuance of a conditional low power license to Seabrook by year-end. Shoreham has had a similar license since 1985. However commercial operation of the two reactors remained uncertain as the opposition on state levels to both remained strong.

Some of the opposition to nuclear reactors took issues to the voters in November. For example in Massachusetts a proposal to close the state's two nuclear plants was defeated by a 68-32 percent margin despite the fact that polls taken early in the year indicated a strong support for closure[11]. Possibly voltage reductions the previous summer had not been forgotten by the voters.

A proposal that Nebraska withdraw from its interstate nuclear waste compact was similarly defeated 63-37 percent. The initiative was considered to be a first step towards retiring the state's two nuclear plants. Its defeat was a surprise in view of the fact that the owners of the plants were enjoined by the state's election commission from campaigning against the measure.

Nuclear power continued to grow in 1988; two reactors reached commercial status and one (Hanford-N unit) was shut down bringing the nation's total number of reactors to 108. In addition to two reactors (South Texas 2 and Shoreham) with low power operating licenses, there were eleven in some stage of construction; however only six have definite operational dates.

As a step toward simplifying licensing of reactors, the Nuclear Regulatory Agency formulated a series of new procedures including pre-approval of standardized reactor designs and a combined site permit and operating license. The latter proposal makes a "one step" process out of the current "two step" procedure that has proven to be time consuming and financially draining.

Nuclear contribution to total electrical generation reached 19.5 percent in 1988 (Table 2). The improvement over 1987 reflects the net increase in the number of operating reactors as well as an increase in annual capacity factors.

Table 2. Electrical generation from nuclear power[4]

1985	Year 1986	1987	1988	
Total utility electrical generation (bn kWh)	2469	2489	2572	2701
Nuclear contribution (bn kWh)	384	414	455	527
Percent nuclear	15.5	16.6	17.7	19.5
Installed nuclear capacity* (GWe)	79.4	85.2	93.6	95.1
Number of operable reactors	95	100	107	108
Annual nuclear capacity factor (%)	58.5	56.9	57	63.5

*Net summer capability of operable reactors

REFERENCES

1. A. L. Austin, Energy Distribution Patterns in the U.S.A. for 1970 and 1985, Lawrence Livermore National Laboratory Report UCID-16022, 1972.

2. I. Y. Borg, Energy-Flow Diagrams: An LLNL Contribution to Energy Analysis, Lawrence Livermore National Laboratory Report MISC-4500, October 1987.

3. C. K. Briggs and I. Y. Borg, U.S. Energy Flow - 1986, Lawrence Livermore National Laboratory Report UCID-19227-86, August 18, 1987.

4. Monthly Energy Review, DOE/EIA-0035 (87/12), March 1988.

5. "Limited pipeline capacity may curb U.S. imports of Canada gas short-term, says NEB," Platts Oilgram 66, No. 243, p.5, December 10, 1988.

6. Executive Gas Industry Statistics, Am. Gas Assoc., Arlington, VA, May 1989, p.2.

7. Gas Energy Review 17, No. 5, American Gas Association, Arlington, VA, May 1989, p. 4 and 15.

8. J. McCaughey, "Will 1988 settle the low v. high growth argument?", The Energy Daily 16, p.1, April 20, 1988.

9. "Bank-Energy Data Bank-Energy Data," The Energy Daily 17, p.4, May 16, 1989.

10. "Non-utility generation up by 10 percent in 1986," The Energy Daily 16, p.4, August 9, 1988.

11. J. Egan, "Nuclear wins along with Bush," The Energy Daily 16, p. 1, November 10, 1988.

12. Annual Energy Review 1988, DOE/EIA-0384(88), June 1988.

13. Quarterly Coal Report, DOE/EIA-0121(87/4Q), Table 31, May 1988.

APPENDIX

Data and Conventions Used in Construction of Energy Flow Charts

Data for the flow chart were provided by tables in the Department of Energy Monthly Energy Review, DOE/EIA-0035,[4] the 1988 Annual Energy Review[12] and the Quarterly Coal Report[13].

The residential and commercial sector consists of housing units, non-manufacturing business establishments, health and education institutions, and government office buildings. The industrial sector is made up of construction, manufacturing, agriculture, and mining establishments. The transportation sector combines private and public passenger and freight transportation and government transportation including military operations.

Utility electricity generation includes power sold by both privately and publicly owned companies. The non-fuel category of end-use consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feedstocks such as ethane, liquid petroleum gases, lubricants, petroleum coke, waxes, carbon black and crude tar. Coking coal traditionally is not included.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75 percent efficiency was assumed which is a weighted average between space heating at approximately 60 percent and electrical lighting and other electrical uses at about 90 percent. Eighty percent efficiency was assumed in the industrial end-use sector and 25 percent in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

There are some minor differences between total energy consumption shown here in the energy flow charts and the DOE/EIA totals given in Table 1. The total energy requirement reported here differs from the total reported by the Department of Energy by one plus quads. The Department of Energy reports the gross amount of energy associated with hydroelectric generation whereas our preference is to report net electrical generation associated with hydroelectric power, i.e., calculated from the number of kWh produced. The difference between the two is the assumed efficiency of the conversion process, plant use combined with distribution losses. Regardless of fuel or resource, the Department of Energy assumes such losses at 66% which may be a good approximation for fossil fuels but is too high for hydroelectric power generation where the conversion efficiency is closer to 80%. By using the net figure rather than the gross for hydroelectric power we omit not only true losses associated with hydroelectric generation but probably some losses that are more properly associated with use of fossil and nuclear fuel.

The industrial consumption total in Table 1 agrees with DOE's net industrial total. Both totals include natural gas lease and plant fuel and non-fuel ("non-energy") use, which are shown separately in the flow charts (Figure 1 & 2). Gross industrial consumption plotted in Figure 3 includes electrical conversion and distribution losses, which are not specifically given in Figures 1 & 2. These losses are included in total electrical generation losses (17.4 Q) associated with utility generation in Figures 1 & 2 because such losses are largely incurred by the utilities supplying the electrical power to the sector.

Conversion Factors

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

Fuel	Energy Content (Btu)
Short ton of coal	22,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,000
Kilowatt hour of electricity	3,400

More detailed conversion factors are given in the Department of Energy's Monthly Energy Review.

0006

Technical Information Department • Lawrence Livermore National Laboratory
University of California • Livermore, California 94550